Dependence of ion-cyclotron range of frequencies instabilities on species mix and fast-ion distribution in DIII-D plasmas*

W.W. Heidbrink (UCI), G.H. DeGrandchamp (LLNL); J.B. Lestz (GA)); K.E. Thome (GA), M.A. Van Zeeland (GA), S. Vincena (UCLA)

Ion cyclotron emission (ICE) driven by fast ions has the potential to be a reactor relevant diagnostic of both confined and lost fast ions; moreover, controlled experiments in magnetic fusion devices can shed light on similar magnetospheric instabilities below and above the ion cyclotron frequency Ω_i. Dedicated DIII-D experiments in 2018 and 2021 studied instabilities above and below Ω_i by injecting thirteen different neutral beam populations into L-mode plasmas with different thermal compositions of H, D, and 3He at five different values of toroidal field. Magnetic loops diagnose mode properties. Each beam type is individually injected for an approximate slowing-down time (~100 ms), resulting in a database of 2529 conditions that are analyzed in frequency bands corresponding to ICE harmonics and $<\Omega_i$ global and compressional Alfvén eigenmodes. The $<\Omega_i$ modes are more unstable at low field and in plasmas with large H concentration. During D injection into H plasmas, sub-cyclotron features appear below both the D and the H cyclotron frequencies. The effect of species mix on ICE stability depends upon the beam population, with most configurations being more unstable in D plasmas but deuterium, co-current, tangential injection showing the opposite effect. Although the frequency of unstable ICE always occurs near the central cyclotron frequency, the precise value also depends on the Alfvén speed and beam direction, consistent with the idea that instability occurs for modes that simultaneously satisfy $\omega \approx \Omega_i$, the magnetosonic dispersion relation, and the $\omega = l\Omega_i - k_\parallel v_\parallel$ resonance condition. The temporal behavior has many interesting effects. For some beam geometries, the ICE emission is much stronger at the beginning of injection, suggesting the importance of "bump-on-tail" energy drive. Sawtooth crashes cause the emission to cease for some beam types and emission bands, but the opposite effect occurs for others. When unstable, for virtually all conditions and frequency bands, the emission bursts in a regular, predator-prey cycle. Evidence for nonlinear interaction between ICE harmonics is observed.

*Supported by DOE DE-SC0021201, DE-SC0020337, and DE-FC02-04ER54698.